Testimony of

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Chairman Inglis, thank you for holding this hearing on the National Nanotechnology Initiative. It is a privilege to testify before you this morning, not only as a representative of Oregon State University (OSU) and the Oregon Nanoscience and Microtechnologies Institute (ONAMI), but also as a scientist interested in the intersection of research and economic development. I spent nearly forty years an academic research scientist and only recently closed my laboratory at Ohio State University to take the post of Vice President for Research at Oregon State University. I am very excited about the opportunity to oversee the OSU research enterprise and to work toward ensuring that innovation at the lab bench contributes to public life, be it through public education, outreach and engagement or business and industry. I also want to acknowledge how pleased we are at Oregon State University that our Representative, Congresswoman Darlene Hooley, is now serving as the Ranking Minority Member on this Research Subcommittee.

My testimony to you this morning comes from the perspective of a research administrator. I am an organic chemist and spent most of my research career focused on the discovery and design of anticancer drugs; I am not an engineer by training nor am I an expert in nanotechnology. However, what I can speak to is the desire of researchers to ask questions and solve problems and what I believe is my responsibility as a research administrator to direct these questions in a way that works to sustain the nation's economic development and global technological leadership, builds an educated workforce, and contributes to public health and security.

I believe these were all goals in the development of the National Nanotechnology Initiative, which was envisioned as a roadmap for the federal government's investments in a critical area of science. In Oregon, we, too, kept these goals in mind as we mapped out our plan to be a part of this scientific revolution and designed a research institute that created innovative new partnerships that cross university, government and industry boundaries that have not previously been formally connected.

Three words describe ONAMI: innovation, collaboration, and commercialization. The Oregon Nanoscience and Microtechnologies Institute is the first "signature research center" funded by the State of Oregon for the purpose of growing research and business development in order to accelerate innovation-based economic development in Oregon and the Pacific Northwest. Oregon policymakers have the goal and desire to establish additional "signature research centers" that will lead to a long-term economic and competitive advantage for Oregon, including commercialization of academic research and the formation of new businesses.

ONAMI is also an unprecedented and powerful collaboration involving Oregon's three public research universities – Oregon State University, Portland State University, and the University of Oregon; the Pacific Northwest National Laboratory (Richland, WA); the state of Oregon; and the emerging "Silicon Forest" high technology industry cluster of Oregon and southwest Washington.

Many factors precipitated this focus on nanotechnology in Oregon. Businesses in Oregon were already leaders in industrial research and development. Intel employs 15,450 employees in Oregon and is the home of the headquarters of their semiconductor technology research and development unit. Hewlett Packard's Ink Jet headquarters are in Oregon and the company's largest and most advanced technology site with 3,900 employees is also located in the state. FEI Company, LSI Logic, Tektronix, Xerox, Invitrogen, InFocus, Pixelworks and Electro Scientific Industries are just a few of the many other technology-based industries with a significant presence in the state. Our proximity to the Department of Energy's Pacific Northwest National

Laboratory (PNNL) was also a factor. PNNL, a $650 million year research operation is the largest R & D operation west of Chicago and North of San Francisco. And, last, but certainly not least, Oregon's three largest research universities have world-class expertise and have decided to collaborate in three critical areas: Microtechnology-Based Energy, Chemical and Biological Systems; Safer Nanomaterials and Nanomanufacturing and Nanoscale Metrology for Nanoelectronics and other applications.

Microtechnology-based Energy, Chemical and Biological Systems, led by Kevin Drost of Oregon State University and Landis Kannberg of the Pacific Northwest National Laboratory, integrates nano-scale materials science and mechanical microstructures to miniaturize a wide range of important devices for both military and commercial use. Translational research and commercialization efforts related to this work will be carried out by the Microproducts Breakthrough Institute (MBI), an ONAMI facility jointly staffed and operated by PNNL and Oregon State University.

These technologies will have widespread commercial application and may well lead to whole new industries. Examples include compact power supplies for portable electronics; vehicular and auxiliary fuel cell systems; distributed biofuel, hydrogen, and chemical production at point-of-use; automotive cooling systems that operate using exhaust heat; and a new generation of distributed heating and cooling systems for residences with energy savings of approximately 50%. OSU researchers in this area are also working with an Oregon company, Home Dialysis Plus (HD+), to develop a compact kidney dialysis machine that will dramatically improve quality of life for end-state renal disease patients while also reducing treatment cost.

The Safer Nanomaterials and Nanomanufacturing research, led by Jim Hutchison of the University of Oregon, is focused on developing functional nanomaterials and nanomanufacturing methods that simultaneously meet the need for high performance materials, protect human health and minimize harm to the environment. This initiative has been focused on the applications of mixed nanoscale and microscale systems to research problems such as those involved in nanomanufacturing. The initiative takes advantage of the world-class expertise within ONAMI in green chemistry, nanoscale materials and processes and the design and fabrication of microscale systems (such as microchannel reactors).

Discoveries in nanoscience are providing new, powerful tools for achieving green chemistry goals such as reducing the use of hazardous materials and improving the efficiency of material and energy consumption. The opportunity exists to apply nanotechnologies to the invention of new products and processes that will produce superior products for less money and simultaneously enhance public security and protect our environment. Researchers within the ONAMI are at the forefront in defining this emerging field with their research programs that focus on safer/greener products <u>and</u> manufacturing methods for making products.

The Nanoscale Metrology Initiative, critical to continued progress in semiconductors and other forms of nano-scale manufacturing, is led by John Carruthers, former director of Components Research and Development for Intel, and Distinguished Professor of Physics at Portland State University (PSU). The team’s efforts are supported by the PSU microscopy facility, which features one of the Pacific Northwest’s most powerful transmission electron microscopes and other instruments that enable the characterization of nanostructures. The ability to design, fabricate and test nanoscale materials and devices depends entirely on the ability to image and measure them, which the network of ONAMI-affiliated user facilities can provide.

The purpose is to initiate additional research in nanometrology and testing of nanodevices and circuits that enables the implementation of nanoscale materials into useful electronic applications such as high density memories on silicon integrated circuits.

This will leverage the large nanotechnology-related investments of LSI Logic, Nantero, Intel, Hewlett-Packard, ESI, FEI Company, and Invitrogen in Oregon's "I-5 Technology Corridor" between Portland and Eugene and ensure that a leading edge research and education capability will be established to further grow the global competitiveness of the nanotechnology industries there.

All of these ONAMI partners came together with several goals in mind: to attract federal research investments in the Oregon and Pacific Northwest; to provide an outstanding collaborative environment for researchers who are at the forefront of innovation in their fields; to increase the impact of this research on Oregon industry; to develop superior workforce talent - especially growth in PhDs; and to spin out the innovations and new companies that will provide the high-wage jobs of the future.

At your request, I am providing to you today responses to the questions you posed examining the challenges and opportunities related to nanotechnology, based on our experiences at Oregon State University and with the Oregon Nanoscience and Microtechnologies Institute (ONAMI).

- **How do Oregon State University (OSU) and the Oregon Nanoscience and Microtechnologies Institute (ONAMI) interface with the private sector? What are the greatest barriers to increased academic/industrial cooperation in nanotechnology?**

In Oregon, the cooperation OSU and our other academic partners have with private sector via ONAMI is unprecedented. Perhaps most notably, Hewlett-Packard developed a very comprehensive inter-institutional agreement with OSU. As a part of this partnership, HP donated the use of a building on their campus in Corvallis, Oregon to accelerate the startup facility. This was a remarkable display of corporate citizenship. This facility serves as a product development space for new ONAMI-related companies while the three universities complete construction of additional ONAMI research facilities. HP donated the three-year lease of the building, valued at $2 million. The construction of new facilities, currently underway, is primarily funded through gifts and state appropriations.

ONAMI Board members include senior executives from some of the world's leading nanotechnology companies: Hewlett Packard, FEI Company (the world leader in tools for nanotechnology, based in Hillsboro, Oregon), LSI Logic and Nantero (a partnership with a focus on nanotechnology-based semiconductor memory development, based in Gresham, Oregon), Pixelworks (the 4th fastest growing company in the US), and Battelle (the operator of 5 national laboratories). The ONAMI board is chaired by a general partner of the state's leading venture capital firm and ONAMI has relationships with many others in the investment community. ONAMI’s sponsored research includes research collaborations with HP, FEI, LSI, Nantero, Xerox, many smaller companies, and Intel. In several cases, we are able to work with industry research and production facilities that are far superior to anything most universities typically acquire. ONAMI also has a physical joint venture with PNNL/Battelle, which is a unique asset for not only performing cutting edge research, but translating that research into new products, new companies, and high-wage jobs.

At Oregon State University, I also want to mention other efforts that keep the university connected to industry. In our College of Engineering, we have a very successful internship program, the Multiple Engineering Cooperative Program (MECOP). This internship experience is so sophisticated it bears little resemblance to the ordinary internships that are increasingly common in higher education. MECOP is, and has been since its inception more than 20 years ago, self-supporting. Dues are paid by participating businesses and industry to support the staff needed to develop, monitor and fine-tune the program. The program is built on a high order of industry interaction with the university and its students; and it is continually improved as the University adjusts its curriculum on recommendations made by the industry partners. Participating industries include Freightliner, Boeing, Sun Microsytems, Tektronix and many, many others. Additionally, as at other institutions, OSU faculty are engaged in industry funded R&D, some researchers utilize their sabbatical leave to gain private industry experience and others take leaves of absence to help start up new companies.

While our ties to private industry are strong, there are existing barriers to collaboration. The first is industry's need to own the intellectual property rights on research they pay for, which can be in direct conflict with faculty and student needs to publish their work, as well as, in some instances, public information laws. An additional barrier is the proprietary nature of private business strategic plans and their internal efforts to achieve them. It is often difficult for academic researchers to know if their work is relevant to industry needs when industry is trying to protect their product development efforts to ensure they are developing unique and competitive products for the marketplace.

Academic and research funding traditions and cultures have traditionally not rewarded (through promotion, tenure, peer reputation) researchers for working in teams, performing industrially relevant research, patenting their inventions, or commercialization. In addition, unpredictable funding processes in both industry and academia also present challenges. Industry also is subject to frequent organizational restructuring involving staff turnover and reassignment.

The lack of research funding for joint industry/university research is a critical barrier and has slowed down several promising opportunities. While larger businesses typically have some kind of R & D budget, this is not the case for smaller, emerging businesses. Generally there is a lack of university funding for what the military calls “6.2” research, research that seeks the application of basic science. The National Science Foundation (NSF) funds nearly exclusively basic science and does not typically fund development. The Defense Advanced Research Projects Agency (DARPA) is the best source for university 6.2 funding, but this often is for highly specialized devices with military applications and without a strong commercial market. ONAMI researchers have expressed a need for a source of funding that could be seen as “a DARPA” for commercial nanotechnology.

- **How does the state of Oregon provide support to OSU and ONAMI for nanotechnology and other high-technology activities? How does this complement funding from the federal government and the private sector? What, if any, gaps remain?**

With unprecedented focus and consensus, Oregon has chosen to focus on Nanoscience and Microtechnologies as the state's first "signature research center", based on a clear finding that this represented the greatest overlap of (1) existing research excellence, (2) future market opportunity, and (3) Oregon's existing industrial strengths. In 2003, the State committed $21 million to ONAMI, and the Governor included $7 million in the proposed state budget for 2005-6. In addition, there is a dedicated State of Oregon Innovation Economy Officer, a proposed statutory Oregon Innovation Council, and state-assisted mechanisms to increase the supply of venture capital by almost $140M, of which over $30M will be pre-seed and seed stage. The state's role is to assist the research institutions in increasing their capacity for competitive sponsored research and to assist entrepreneurs in commercializing new technology.

Industry support of ONAMI's operation since its inception has totaled approximately $10 million in equipment, facilities use commitments, R&D, and gifts. Other research awards have totaled approximately $25 million, including federal awards from the Department of Defense and NSF, as well as foundation awards. Oregon State University's commitment thus far, outside of the specified state appropriations for ONAMI, is estimated to be approximately $3 million.

Again, the gap between state, federal and private support is in support for investigations in technologies that are beyond the basic research, but not quite ready to be tested for commercialization. Smaller businesses often simply do not have research budgets to support these needs, and government funding for this stage of inquiry is not widely available.

- **What is the workforce outlook for nanotechnology, and how can the federal government and universities help ensure there will be enough people with the relevant skills to meet the nation's needs for nanotechnology research and development and for the manufacture of nanotechnology-enabled products?**

During the December 2004 Oregon Leadership Summit Steve Grant ,Vice President for the Technology & Manufacturing Group at Intel Corporation reported that, "Over the last 4 years, Intel has hired 441 PhD's in engineering and computer science in Oregon. Only 7 came from the Oregon University System. [Intel] hired 347 master's degree engineers and only 11% came from Oregon schools. At the bachelor degree level [they] did better, with 21%." Oregon is not producing enough highly skilled quality engineers to meet our hiring needs, especially at the graduate levels. However, this is not just the case in Oregon, it is a problem nationwide.

Increased barriers to American colleges and universities for foreign students, as well as greatly enhanced opportunities for them at home, and a lack of progress in filling the pipeline with qualified American students are trends in direct opposition to an increased need for workers with advanced degrees in physical sciences and engineering. Without a trained workforce, the United States will find it hard to remain a leader in nanotechnology. Further, intense global competition has reduced industry's investment in scientific research, while the federal government investment in research that will lead to technology-based economic development has stagnated. This is a confluence of unfavorable trends.

I know you have heard this message repeatedly, but federal funds for physical science and engineering are a part of what is needed to address the work force issue. In the end, faculty and graduate students go where the money is and funding for nanotechnology research is critical for producing the graduate level workforce that nanotechnology-based industry needs. Since World War II, the federal government has supported training grants and research assistantships hand-in-hand with support for basic research. The combination of study and training is a successful avenue to train a highly educated workforce.

We also need a greater emphasis on curriculum development at all levels with serious research on what academic skills are needed for the emerging technologies, best practices in science and engineering education need to be identified and disseminated throughout the academic community.

What is also critical is inspiring young students, in elementary school, high school, and as undergraduates to see themselves as scientists and to be exposed to exciting new and multi-disciplinary trends. We need more students to find scientific concepts practical and approachable and we need to inspire them to consider careers in science. At Oregon State University, we are host to numerous outreach programs that try to get the attention of future scientists and engineers. Many of these programs, too, are federally funded, such as the NSF GK-12 graduate fellowship program, and the NASA Space Grant program, and I encourage you to continue to invest in these activities and to work toward ensuring that they are administered in a way that ensures their effectiveness. I also think that there should be ways to encourage novel curricular changes.

- **How can federal and state governments, industry, and academia best cooperate to facilitate advances in nanotechnology?**

It is generally recognized that university-based research is a long-term investment in the future. The federal government's support for basic research contributes to the discoveries and innovation that underpins the future technologies and knowledge that contribute to the well-being of our nation. However, as our scientists get involved in areas of research, such as nanotechnology, where there are demands for near-term delivery, many challenges emerge.

In order to facilitate advances in these areas, one possible solution is to establish federal funding sources that set clear objectives related to translation of technology and economic development, put in place metrics to measure progress against these goals, and hold recipients of funding accountable for achieving outcomes. While this is not an appropriate direction to take with basic research, there are ways to designate a certain percentage of publicly funded research for multi-disciplinary teams focused on big and emerging fields with a potential for translation and commercialization. An example of this is the NIH Roadmap Initiative and the National Cancer Institute (NCI) National Cooperative Drug Discovery Programs (NCDDGs).

As I noted earlier, three words describe ONAMI: innovation, collaboration, and commercialization. If federal and state governments, industry, and academia can all keep these in mind as they examine avenues to advance nanotechnology research and development, it is the public that will benefit—from individuals who can take advantage of such devices as compact, portable, home kidney dialysis devices to communities which experience economic prosperity with the establishment of new nanotechnology businesses and industry.

In conclusion, I wish to thank you for this opportunity to address you today. Nanotechnology is an exciting new area which will have tremendous impact across multiple fields of science and throughout many aspects of our lives. We are excited that in Oregon we have been able to develop a vision for significant partnerships such as ONAMI and that private, state, federal and university investments have made the vision a reality.

BIOGRAPHICAL SKETCH

John M. Cassady received a B.A degree from DePauw University in 1960 with a major in chemistry; he obtained his M.S. degree in 1962 and his Ph.D. degree in 1964 from Western Reserve University with a major in Organic Chemistry. Dr. Cassady was an NIH postdoctoral fellow from 1965-1966 at the University of Wisconsin where he worked under the direction of Dr. Morris Kupchan on the isolation and structural elucidation of tumor inhibitors from plants. In 1966, he joined the faculty of the School of Pharmacy, Purdue University as Assistant Professor in the Department of Medicinal Chemistry and Pharmacognosy. He was promoted to Associate Professor in 1970 and Professor in 1974. He was appointed Associate Head of the Department of Medicinal Chemistry and Pharmacognosy in 1976 and became Head of the Department in January 1980. In 1987, Dr. Cassady was appointed as the Glenn L. Jenkins Distinguished Professor of Medicinal Chemistry and Pharmacognosy at The Ohio State University College of Pharmacy. On July 1, 2003 he returned to the faculty after more than 15 years as Dean. Dr. Cassady was appointed as Vice President for Research at Oregon State University, March 2005.

Dr. Cassady holds membership in the American Chemical Society, American Society of Pharmacognosy (ASP), Academy of Pharmaceutical Sciences, British Chemical Society, AACR, ASHP, AAAS, Sigma Xi, Rho Chi, and the AACP. He has served on the nominating and publicity committees for the ASP, was scientific program chairman for the 1976 annual meeting of the Society, was elected to the Executive Committee (1978-1981) and President (1993-1994) and is chair of the ASP Foundation Board (1995-present). He has served as a consultant to the National Institutes of Health and was a member of the Bioorganic and Natural Products Study Section from 1980-1984. He has served on the Editorial Advisory Board of the *Journal of Natural Products* and the *Journal of Medicinal Chemistry*. Dr. Cassady has served on the publicity, scientific program and awards committees for the Medicinal Chemistry Division of the American Chemical Society. He was appointed a member of the Long-Range Planning Committee of the Medicinal Chemistry Division from 1983-1986 and in 1987 he was elected Councilor for the Medicinal Chemistry Division. He was appointed to the National Association of Chain Drug Stores (NACDS) National Advisory Council from 1997-2002. He was a member of the AACP National Commission on Graduate Education (1996-1998), Chair of the AACP Institutional Research Advisory Committee (1997-1998), and a member of the Ad Hoc Committee on Academic Budgeting and Accountability (1997-1998). He was elected AAAS Chair-elect for the Section of Pharmaceutical Sciences in 1997 and served as chair in 1999-2000. He served on the ASHP Commission on Goals in 2001 and 2002. He currently serves on the Corporate Advisory Board of Pacific Northwest National Laboratories (PNNL).

Dr. Cassady’s research interests involved the discovery and design of anticancer drugs from natural products and nutraceuticals, specifically, the isolation, structural elucidation, and chemical studies of chemopreventive and antitumor agents from higher plants and the synthesis of potential antitumor agents. Other areas of research interest involved the design of enzyme inhibitors, including protein tyrosine kinases, synthesis of selective dopamine agonists as potential antipsychotic agents, anti-malarial and anti-Parkinson’s agents from natural products. His research resulted in the publication of more than 150 manuscripts and 150 abstracts and over $12,000,000 in research support from the NIH and other funding agencies. Dr. Cassady has developed strategic alliances between academic and corporate sectors. He led a strategic alliance with Pharmacia, served on the Corporate Advisory Board of Yuhai Phytochemicals, China, Dean’s Advisory Board for Merck-Medco and as a consultant for Gaia Botanicals, Leadscope, Milkhaus and SSCI.

Dr. Cassady was elected to membership in the Royal Society of Chemistry and American Association for Advances in Cancer Research, was elected a Fellow of the Academy of Pharmaceutical Sciences in 1979, a Fellow of the American Association of Pharmaceutical Sciences in 1987 and a Fellow of the AAAS in 1990. Dr. Cassady received the Purdue University Cancer Research Award in 1981 and the Gisvold Lecture Award from the University of Minnesota in 1986. In June 1989, he was awarded the D.Sc. (Hon.) by DePauw University. He received the Research Achievement award in Natural Products Chemistry from the American Pharmaceutical Association in 1990. In 1991, he was appointed Honorary Professor to the Institute of Medicinal Plant Development by the Chinese Academy of Medical Sciences.